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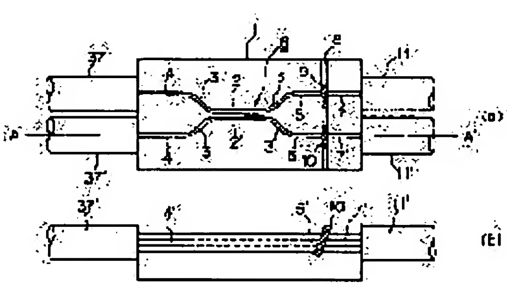
(54) OPTICAL WAVEGUIDE WITH INTERFERENCE FILTER

(57)Abstract:

PURPOSE: To obtain an optical waveguide with interference filters which has a large reflection attenuation quantity without decreasing the operability and increasing the chip size by slanting the groove into which the interference filters are inserted to a depth direction.



CONSTITUTION: The interference filters 9 and 10 are disposed between straight optical waveguides 5 and 7 for output optical fiber connection and straight optical waveguides 5' and 7' for output optical fiber connection. The interference filters 9 and 10 are inserted into the groove formed crossing the optical waveguides. This groove 8 is perpendicular or parallel to the segmented flank of the optical waveguide chip and slants at a tilt angle θ=6° to a substrate surface in a vertical direction, i.e., depth direction. The groove 6 can, therefore, be machined by fixing the substrate surface of a wafer to a pedestal which slants at the angle of 6°. Thus, the groove 8 is slanted, so low loss, good wavelength separation, the high reflection attenuation rate, and good operability are obtained and the productivity can be improved without increasing the chip size.

* NOTICES *

JP 05-333,222 translation

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] This invention is used for optical electrical transmission, optical signal processing, etc. by two or more wavelength about the optical waveguide which gave the wavelength selection function.
[0002]
[Description of the Prior Art] If an interference filter is loaded in a part of optical waveguide, the wavelength selection function of an interference filter can be added to an original optical waveguide function. An example of the optical waveguide with an interference filter created for such the purpose is shown in drawing 5 (an "optical multiplexer/demultiplexer" besides Takato, JP,63-33713,A). Drawing 5 R> 5 (a) is the top view of optical waveguide, and drawing 5 (b) is an A-A' line (optical axis) sectional view in this (drawing a) perpendicular to a substrate side. Deflection optical waveguide 3a for optical-path conversion connected to the ON appearance side of each joint optical waveguide 2a and 2'a while joint optical waveguide 2a which constitutes directional coupler 6a, and 2'a are formed in substrate 1a, as shown in this drawing is formed respectively. Furthermore, the straight-line optical waveguides 5a and 7a for output optical fiber connection and 5 'a, 7' a linked to straight-line optical waveguide 4for input optical fiber connection a linked to the input side of deflection optical waveguide 3a for optical-path conversion, 4'a, and its output side are formed.
[0003] Among the straight-line optical waveguides 5a and 7a for output optical fiber connection, and between straight-line optical waveguide 5 'a and 7' a for output optical fiber connection, interference filters 9a and 10a are infixed. Interference filters 9a and 10a are inserted in slot 8a formed by crossing optical waveguide. It is connected so that optical fiber 11a and 11'a may correspond with straight-line optical waveguide 4for input optical fiber connection a, and 4'a and the optical axis of 37'a [optical fiber 37a and] of both may correspond with straight-line optical waveguide 7for output optical fiber connection a, and 7'a respectively again. In the optical waveguide with an interference filter of such a configuration, if the light of wavelength lambda1 and lambda2 is inputted from one input optical waveguide 37a, in directional coupler 6a, only the light of wavelength lambda 1 will join together among the light of wavelength lambda1 and lambda2 to joint optical waveguide 2a[from joint optical waveguide 2a]'. That is, the light of wavelength lambda 1 separates to optical waveguide 5'a, the light of wavelength lambda 2 separates to optical waveguide 5a, and it spreads.
[0004] However, since the wavelength degree of separation of directional coupler 6a are not enough, the light of wavelength lambda1 and lambda2 is completely inseparable into each optical waveguide 5'a and 5a. Then, it is supposed by giving wavelength selection nature different, respectively to interference filters 9a and 10a that the light of wavelength lambda1 and lambda2 will be separated completely. That is, the light of wavelength lambda1 and lambda2 is completely separable by penetrating the light of wavelength lambda 2 for interference filter 9a, and reflecting the light of wavelength lambda 1, and penetrating the light of wavelength lambda 1 for interference filter 10a, and reflecting the light of wavelength lambda 2. For example, when using the wavelength of 1.5-1.6 micrometers, the wavelength of 1.25-1.35 micrometers, and the light of a large wavelength range as wavelength lambda1 and lambda2, it becomes 1dB of loss, and 25dB of degree of separations, and the sufficiently practical spectral separation property is acquired.

[0005] By the way, in interference filters 9a and 10a, since the permeability of each transmitted wave length is not 100%, not only the wavelength component of the reflective band of a filter but the wavelength component of a transparency band is contained in the reflected light reflected in respect of a filter. When for this reason the reflected light from interference filters 9a and 10a spreads to hard flow to optical waveguide 5a and 5'a and returns to the light source, there is a problem on which unstable actuation of the light source is invited, consequently an electrical transmission property deteriorates. For this reason, it has been important conditions to make it the reflected light from interference filters 9a and 10a not return to the light source as much as possible, when optical waveguide with an interference filter is constituted.

[0006] Then, it is not perpendicular to optical waveguide 5a and 5'a in the filter side of interference filters 9a and 10a, and he makes the reflected light of interference filters 9a and 10a emit out of the core of optical waveguide 5a and 5'a, and is trying not to combine with incore [of optical waveguide 5a and 5'a] by [fixed] leaning the degree of angle in the former. By doing in this way, the reflected light decreases only a part to be shown in a degree type.

L=-10, log [exp-(2pinw theta/lambda) 2] -- (1)

However, for a reflective attenuation factor (ratio of Unit dB, filter input light, and the reflected light), and w, a mode field radius (m) and theta are [L / wavelength (m) and n of the tilt angle (a unit radian, angle of inclination from a perpendicular direction) of an interference filter and lambda] the refractive indexes of optical waveguide. As the tilt angle theta is enlarged so that clearly from this formula (1), the reflective attenuation factor L is large, that is, attenuation of the reflected light becomes larger. Moreover, if the required reflective attenuation factor L is known, only the tilt angle theta calculated from a formula (1) should lean an interference filter.

[0007]

[Problem(s) to be Solved by the Invention] However, since interference filters 9a and 10a are inserted in slot 10of substrate 1a a, in order to make interference filters 9a and 10a into the tilt angle theta to optical waveguide, slot 10a is made to incline with the tilt angle theta in the field of substrate 1a in the conventional optical waveguide with an interference filter. For this reason, there were the following problems by the former. That is, as shown in drawing 6 , when producing many rectangular substrates from circular wafer 12a in which two or more optical waveguides (illustration abbreviation) are formed, generally jump-off lines 13a and 14a are formed in circular wafer 12a in a grid pattern. And many substrates of the rectangle divided by jump-off lines 13a and 14a are produced as an optical waveguide chip by starting wafer 12a at once along with jump-off lines 13a and 14a.

[0008] Here, as shown in drawing 5 , in case an I/O optical fiber is connected with the cut-down optical waveguide chip, in order to make in agreement the optical axis of an optical fiber and optical waveguide, it is set up so that logging line 13a may become I/O optical waveguide and parallel and logging line 14a may become I/O optical waveguide and a perpendicular. For this reason, recessing of the slot where an interference filter is inserted in the substrate side of a wafer is carried out so that it may become the tilt angle theta to logging line 14a. Consequently, the location of the slot in each optical waveguide chip in the condition of a wafer turns into a location different, respectively. Such a location gap of a slot turns into 1.1cm (=10 cmxtan6") location gap in general, when becoming max among the optical waveguide chips 16a and 17a which separated most on wafer 12a, for example, forming a slot with a tilt angle of theta= 6 degrees on a 4 inches wafer.

[0009] A slot location eats into fields, such as a directional coupler, when the worst, the slot location shifted and even the next chip was to be able to form a slot in a location to form in originally for this reason. Then, although this is avoidable if the part of a gap is beforehand expected in the setting phase of optical waveguide, the dimension of a chip becomes large and the chip volume per wafer falls remarkably. Although a chip dimension cannot be enlarged and a slot can be processed on the regular location if recessing is carried out separately after starting for an optical waveguide chip in order to avoid this, there is a problem to which workability falls sharply. This invention aims at offering the optical waveguide with an interference filter of high return loss, without being made in view of the above-mentioned conventional technique, not reducing workability, and enlarging the dimension of a chip.

[0010]

[Means for Solving the Problem] The configuration of this invention which attains this purpose forms

the slot which crosses this optical waveguide while constituting the photoconductive wave circuit which consists of optical waveguide on a substrate, and in the optical waveguide with an interference filter which comes to insert an interference filter in this slot, said slot is perpendicularly characterized by the predetermined thing being done for the include-angle inclination to the depth direction.

[0011]

[Example] Hereafter, this invention is explained to a detail with reference to the example shown in a drawing. One example of this invention is shown in drawing 1 - drawing 4 . As shown in this drawing, while the joint optical waveguide 2 and 2' which constitute a directional coupler 6 are formed in the Si substrate 1, each joint optical waveguide 2 and the deflection optical waveguide 3 for optical-path conversion linked to the ON appearance side of 2' are formed respectively. furthermore -- an optical path -- conversion -- ** -- deflection -- optical waveguide -- three -- an input side -- connecting -- an input -- an optical fiber -- connection -- ** -- a straight line -- optical waveguide -- four -- four -- ' -- and -- the -- an output side -- connecting -- an output -- an optical fiber -- connection -- ** -- a straight line -- optical waveguide -- five -- seven -- and -- five -- ' -- seven -- ' -- forming -- having -- **** . optical waveguide -- two -- two -- ' -- three -- four -- four -- ' -- five -- five -- ' -- seven -- and -- seven -- ' -- specific refraction -- a rate -- delta -- = -- 0.3 -- % -- eight -- micrometer -- x -- eight -- micrometer -- a core -- a configuration -- having -- **** . A directional coupler 6 has the property of separating light with a wavelength of about 1.3 micrometers and light with a wavelength of about 1.55 micrometers.

[0012] Interference filters 9 and 10 are arranged among the straight-line optical waveguides 5 and 7 for output optical fiber connection, and between straight-line optical waveguide 5' for output optical fiber connection, and 7'. Interference filters 9 and 10 are inserted in the slot 8 formed so that optical waveguide might be crossed. This slot 8 is perpendicular or parallel to the logging side face of an optical waveguide chip. Moreover, this slot 8 inclines with the tilt angle of theta= 6 degrees perpendicularly to a substrate side, i.e., the depth direction. The width of face of this slot 8 is 40 micrometers, the width of face of interference filters 9 and 10 is 30 micrometers, and interference filters 8 and 10 are being fixed in the slot 8 by the binder. An interference filter 9 is a long wavelength passage mold filter with the property of penetrating light with a wavelength of 1.3 micrometers, and being a short wavelength passage mold filter with the property of reflecting light with a wavelength of 1.55 micrometers, and an interference filter 10 penetrating light with a wavelength of 1.55 micrometers, and reflecting light with a wavelength of 1.3 micrometers. On the other hand, it connects so that an optical fiber 11 and 11' may correspond with the straight-line optical waveguide 4 for input optical fiber connection, and 4' and the optical axis of 37' [an optical fiber 37 and] of both may correspond with the straight-line optical waveguide 7 for output optical fiber connection, and 7' respectively again.

[0013] The optical waveguide with an interference filter of this example which has the above-mentioned configuration is produced as follows. First, quartz-glass optical waveguide is produced by soot deposition, vitrification processing, and the patternizing by dry etching on Si substrate in the condition of a wafer (322 22 N. Takato et.al. Electron.lett.vol. pp.321- 1986). TiO2 is added by SiO2 glass several%, and the refractive index of optical waveguide is controlled by the addition of TiO2 by optical waveguide.

[0014] Subsequently, to the circular wafer 12, as shown in drawing 2 , along with the broken line 15, sequential formation of the slot was carried out so that it might become the logging line 13 with an abbreviation perpendicular. The wafer 12 was fixed to the plinth 18 and formation of a slot used the commercial dicing saw. The plinth 18 inclines so that the include angle whose substrate side of a wafer 12 is 6 degrees may be made to the blade 19 of a dicing saw. For this reason, to the logging line 13, the slot produced by the wafer 12 is an abbreviation perpendicular, to the depth direction, perpendicularly, makes the include angle of 6 degrees and will incline [as opposed to / that is, / that substrate side]. The wafer 12 was transferred to another plinth (illustration abbreviation) after recessing, it started for the optical waveguide chip along with the logging lines 13 and 14, the interference filter was inserted in the slot after that, and it fixed with the binder. Then, it connected with the single mode fiber with a% [of rates of specific refraction] of delta= 0.3, and a core diameter of 9 micrometers, and considered as optical waveguide with an interference filter. Thus, much optical waveguides with an interference filter shown in drawing 3 were producible.

[0015] It measured about the property of the produced optical waveguide with an interference filter. Consequently, when the latter was divided into optical fiber 11' and the former was outputted to the

optical fiber 11 from one optical fiber among mixed light (the 1.25-1.35-micrometer wavelength band which carried out incidence, and 1.5-1.6 micrometers), the loss was about 1dB. Moreover, the amount which the light of wavelength degree of separation, i.e., one wavelength band, mixes in the light of the wavelength band of another side was -55dB. Furthermore, 55dB considered to be a measurement limitation by the effectiveness to which the reflective attenuation factor leaned the interference filter to 6 degrees in the main wavelength of 1.31 micrometers of both bands and 1.55 micrometers was obtained. The optical waveguide with an interference filter of this example is low loss, wavelength degree of separation and a reflective damping force are high, and workability is good, and does not enlarge a chip dimension, and productivity is excellent.
[0016] Next, the second example of this invention is explained with reference to drawing 3 R> 3. In this example, two or more optical waveguides are formed in 1 chip using wavelength a non-depended directional coupler. That is, while two or more directional couplers 20 are arranged on a substrate 1, these are connected to optical fiber 18 for I/O, 18', 19, and 19' through optical waveguide 24, 24', 25, 25', 26, and 26', respectively. The all directions tropism coupler 20 did not wavelength depend, the minute optical path difference is given between two arms of the Mach-Zehnder interferometer which consists of two directional couplers 21 and 22, and the good joint property of surface smoothness is acquired (Kjinguji, 'Mach-Zehnder interferometer type optical waveguide coupler with wavelength-flattened coupling ratio', Electronics letters, vol.26, and p.1326 (1990)). It is formed by the same approach as the first example which the input optical waveguide 24 and the slot 23 which crosses 24' mentioned above in the substrate 1, and the interference filter 27 is inserted in this slot 23. As long as some increases of loss are permitted, an interference filter 27 may be arranged in the optical waveguide 26 for a bend section, and 26'.
[0017] The optical waveguide with an interference filter of this example is suitable as an optical accessor used by the trial of an optical fiber etc. To for example, the midst which connected the laser diode of wavelength lambda 1 to the optical fiber 18 for an input, connected the optical-fiber-transmission way to the optical fiber 19 for an output, and has sent out the lightwave signal to the transmission line from the laser diode The pulse test light of the wavelength lambda 2 by the light pulse tester (OTDR:Optical Tim Domain Refrectometer) is introduced into an optical-fiber-transmission way through a bond part from optical fiber 18for input' of another side. Troubleshooting of optical waveguide can be performed ("construction of beam-of-light way trial and managerial system" 1990 electronic communication link informatics [besides Tomita] meeting spring national conference collected works, B-888). Under the present circumstances, the light of wavelength lambda 1 is penetrated as an interference filter 27, and if what intercepts the light of wavelength lambda 2 is used, a light pulse trial can be performed, without affecting a lightwave signal. And since the interference filter is leaned, there is almost no reflected light which returns to a laser diode.
[0018] Next, the third example of this invention is explained with reference to drawing 4 R> 4. This example omits a directional coupler and gives only the wavelength selection properties of an interference filter. That is, an interference filter 29 is arranged in the straight-line optical waveguide 28 prepared in the substrate 1, and the interference filter 29 is inserted in the slot formed by the same approach as the example mentioned above. The straight-line optical waveguide 28 has only the function which guides light, and does not have wavelength selection properties. In this example, since it does not have a directional coupler, if it is possible to make a chip dimension very small, for example, 2 costs 3x5mm as necessary minimum magnitude in consideration of the handling nature of a chip, optical waveguide with about 500 interference filters is producible from a 4 inch wafer. In addition, the class of the class of optical waveguide used in the above-mentioned example and a process, and interference filter etc. is an example, and this invention is not restricted to the above-mentioned example as the process of optical waveguide, the classes of interference filter, etc., such as a class of optical waveguide which should add a filtering function, and an ionic diffusion.
[0019]
[Effect of the Invention] As mentioned above, it becomes possible to raise productivity remarkably, without optical waveguide with an interference filter with a high reflective damping factor not reducing workability with sufficient wavelength degree of separation by low loss as for this invention, and enlarging the dimension of a chip, as concretely explained based on the example.

[Translation done.]

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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] The top view of the optical waveguide with an interference filter which this drawing (a) requires for the first example of this invention, and this drawing (b) are A-A' line sectional views in this drawing (a).
[Drawing 2] The top view of a wafer in which the logging line was formed in a grid pattern, and this drawing (b) of this drawing (a) are side elevations of the wafer fixed to the plinth.
[Drawing 3] It is the top view of the optical waveguide with an interference filter concerning the second example of this invention.
[Drawing 4] It is the top view of the optical waveguide with an interference filter concerning the third example of this invention.
[Drawing 5] This drawing (a) is a top view of the conventional optical waveguide with an interference filter, and this drawing (b) is an A-A' line sectional view in this drawing (a).
[Drawing 6] A logging line is the top view of the wafer formed in a grid pattern.
[Description of Notations]
1 Substrate
2a, 2'a, and 3a, 4a and 4 -- a, 5a, 5'a, 2, 2', 3 and 4, 4', '5, 5', and 24, 25, 26 and 28 Optical waveguide
7, 7', and 7a and 7 -- a, 11, 11', 11a, 11'a, 18, 18', and '19, 19' Optical fiber
6, 6a, 20, 22 Directional coupler
8 23 Slot
9, 9a, 10, 10a, 27, 29 Interference filter
12 12a Wafer
13, 13a, 14, 14a Chip logging line

[Translation done.]